

POSTURAL CONTROL DISTURBANCES PRODUCED BY EXPOSURE TO HMD AND DOME VR SYSTEMS

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INTRODUCTION. Two critical and unresolved human factors issues in VR systems are: 1) potential "cybersickness", a form of motion sickness which is experienced in virtual worlds, and 2) maladaptive sensorimotor performance following exposure to VR systems. Interestingly, these aftereffects are often quite similar to adaptive sensorimotor responses observed in astronauts during and/or following space flight. Most astronauts and cosmonauts experience perceptual and sensorimotor disturbances during and following space flight. All astronauts exhibit decrements in postural control following space flight. It has been suggested that training in virtual reality (VR) may be an effective countermeasure for minimizing perceptual and/or sensorimotor disturbances. People adapt to consistent, sustained alterations of sensory input such as those produced by microgravity, and experimentally-produced stimulus rearrangements (e.g., reversing prisms, magnifying lenses, flight simulators, and VR systems). Adaptation is revealed by aftereffects including perceptual disturbances and sensorimotor control disturbances. The purpose of the current study was to compare disturbances in postural control produced by dome and head-mounted virtual environment displays.

METHODS. Twenty-one subjects (11 men, 10 women) participated in the study with an age range of 28-49 years old. One training session was completed in order to achieve stable performance on the posture and VR tasks before participating in the experimental sessions. Three experimental sessions were performed each separated by one day (e.g. MWF). The subjects performed a navigation and "pick and place" task in a dome VR system for either 30 or 60 min. The environment was a square room with 15 pedestals on two opposite walls. The objects appeared on one set of pedestals and the subject's objective was to move the objects to the other set of pedestals. After the subject picked up an object, a pathway appeared and they were required to follow the pathway to the other side of the room. The subject was instructed to perform the task as quickly and accurately as possible, avoiding hitting walls and other any obstacles and placing the object on the center of the pedestal. Postural equilibrium was measured (using the Equitest CDP balance system, Neurocom, International) before, immediately after, and at 1 hr, 2 hr, 4 hr and 6 hr following exposure to VR. Postural equilibrium was measured during quiet stance with eyes open, eyes closed and vision and/or ankle proprioceptive inputs selectively altered by servo-controlling the visual surround and/or support surface to the subject's center of mass sway. Identical procedures were followed for a group 10 subjects who used a VR-4 head-mounted display system.

RESULTS. In general, we found that exposure to VR resulted in decrements in postural stability. The largest decrements were observed in the tests performed immediately following exposure to VR and showed a fairly rapid recovery across the remaining test sessions. Subjects performed worse immediately after exposure to VR (0hr post) compared to pre, 1hr, 2hr and 4hr post (Composite EQ Score: $p < .01$, $p = .04$, $p = .02$, $p < .0001$; SOT6 EQ Score: $p = .02$, $p = .005$, $p = .01$, $p < .0001$). In addition, postural equilibrium scores were higher on days 2 and 3 than on day 1 (Composite EQ Score: $p < .0001$, $p < .0001$; SOT5 EQ Score: $p = .02$, $p < .0001$; SOT6 EQ Score: $p < .0001$, $p < .0001$). We found no evidence that post-VR postural instability was greater following 60 min than 30 min exposures. Subjects experienced significantly less severe motion sickness on day 3 compared to day one ($p = .003$). Subjects experienced significantly more severe motion sickness immediately after exposure to VR than pre, 1hr, 2hr and 4hr post (all p values were less than .0001). Our findings are consistent with those reported previously concerning astronauts. Preliminary observations of the data from subjects who performed the task using and HMD are similar to those who used the dome system.

CONCLUSION. Individuals recovered from motion sickness and the detrimental effects of exposure to virtual reality on postural control within one hour. Sickness severity and initial decrements in postural equilibrium decreases over days, which suggests that subjects become dual-adapted over time. These findings provide some direction for developing training schedules for VR users that facilitate adaptation, and address safety concerns about aftereffects.